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EVALUATION OF A POLYURETHANE/POLYSTYRENE COMPOSITE CUSHIONING M--ETC(U)
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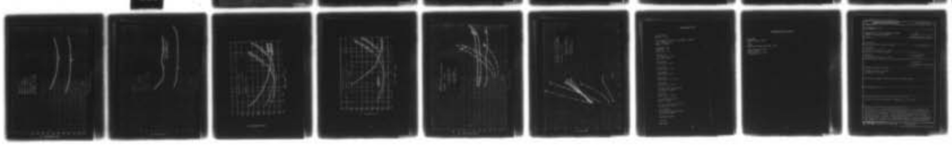

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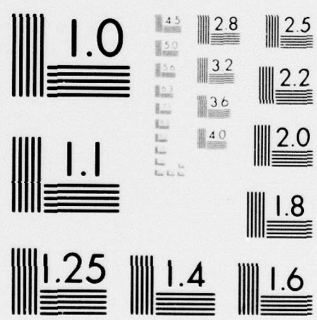

MICROCOPY RESOLUTION TEST CHART

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6 EVALUATION OF A POLYURETHANE/POLYSTYRENE
COMPOSITE CUSHIONING MATERIAL

HQ AFALD/PTP
AIR FORCE PACKAGING EVALUATION AGENCY
Wright-Patterson AFB OH 45433

11 July 1979

NOTICE

ABSTRACT

An evaluation of a polyurethane/polystyrene composite cushioning material revealed that the dynamic cushioning characteristics of this material has a broader static stress range, for a specific peak acceleration, than some of the existing 2 pcf materials listed in the Military Handbook 304A, "Package Cushioning Design". Samples of materials identified as structural grade and cushioning grade together with intermediate grades of material formulations, were analyzed to determine the effect of the expanded polystyrene beads in the material formulation.

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INTRODUCTION

Numerous samples of the polyurethane/polystyrene composite cushioning material were evaluated to determine what effect the polystyrene bead content had on dynamic cushioning characteristics.

Because of the large quantity of samples required to complete the tests, the majority of the data is for a drop height of 24 inches and a static stress range of 0.06 to 0.1 psi.

A detailed investigation of a composite cushioning material was conducted by the Naval Weapons Support Center[1] in December 1976.

DESCRIPTION OF MATERIAL

The polyurethane/polystyrene composite material consists of a polyurethane matrix with expanded polystyrene beads which are uniformly distributed throughout the polyurethane. The density, Indent Load Deflection (ILD) factors, percent of bead content and the bead size varied for some of the samples tested. To eliminate the many variables in the material formulation, a set of samples with only the bead content as the variable[2] were included in this evaluation.

The material identified as cushioning grade was designed primarily for the furniture industry and the structural grade was formulated for packaging material. The percent of bead content is by weight. Sample thicknesses of two and four inches were evaluated. A detailed description of the samples are listed in Table I of the appendix.

Test Instrumentation and Equipment

The following instrumentation and equipment was employed during this evaluation:

1. Oscilloscope, 4 channel storage, Tektronix Model 564-B
2. Accelerometer, Statham Model A5-100-350
3. Amplifier, Sensotec Model RM-6
4. EPUT/Timer, Beckman-Berkeley, Model 7360R
5. Hardigg Cushion Tester, Hardigg Industries, Inc. Model 3

[1] Wiegand and Smith, "Investigation of a Shock Mitigating Composite Foam" (Report Nr. NWSC/CR/RDTN-31), Naval Weapons Support Center, Applied Science Department, Crane, Indiana 47522

[2] Although the sample densities varied with the bead content, the density of the polyurethane material itself was held constant.

Test Procedures

The dynamic cushion characteristics test was conducted in accordance with ASTM Test Method D-1596, Dynamic Properties of Package Cushioning Materials. The sample sizes were 8 X 8 X 2 inches and 8 X 8 X 4 inches. The majority of the drop tests were conducted at a height of 24 inches and a static stress (weight/area) range between 0.066 and 1 psi. Limited data were also obtained for the structural grade material at drop heights of 36 and 42 inches.

Test Results

All of the test results are presented graphically on semi-logarithmic two cycle graph paper. Graphs 1 and 1a reveal the effect of the polystyrene beads which were added to the polyurethane matrix. Increasing the bead content decreased the peak acceleration at the high static stress range and increased the peak acceleration at the low static stress range. These samples were formulated specifically for this test series to determine the effect of the bead content. The sample numbers on each graph can be matched with the sample numbers in Table 1.

Graph 2 compares a polyurethane sample without beads with the 9% bead content of the cushioning grade. Graph 3 compares the 15% bead content of the structural grade with a sample without beads.

Variations of the cushioning and structural grades were made by using a soft polyurethane matrix and increasing the polystyrene bead content. Graph 4 reveals the results of the intermediate grade which has a bead content of 13%. In graph 5 the bead content was increased to 18%. For the 2 inch thick sample note the effect of bead compression which results in an irregularity in the static stress range of 0.15 psi.

In graph 6 the 13% intermediate grade is compared with polyurethane and polyethylene foam, 2 pound density listed in Military Handbook 304A. Note the broad static stress range for the composite (sample 9) as compared to the other materials. The composite sample 9 is also compared to 4 pound density polyurethane and polyethylene in Graph 7.

The Gm - W/A data for sample 14 were generated for drop heights of 24, 36 and 42 inches and a static stress range of 0.07 to 0.9 psi (graph 8).

In graph 9 the data for sample 14 (acceleration vs. drop height) reveals that the standard structural grade material will protect an item to 42 Gs at a drop height of 30 inches even though the static stress varies from 0.1 to 0.5 psi. This data also reveals that the composite is superior to the polyurethane as the drop height increases because the polystyrene beads begin to compress at a static stress of 0.3 psi.

Discussion

The addition of expanded polystyrene beads in varying proportions in a polyurethane matrix could enable a manufacturer to formulate cushioning material which would meet special packaging requirements for specific items. Also one formulation, such as the structural or intermediate grades, would provide approximately the same shock level protection for items which have various weights and surface areas. This could reduce the need for a large number of cushioning material types and thicknesses in organizational inventories.

Cost Analysis: Accurate manufacturer's cost data for the various composite materials tested was not available; however, the estimated relative cost information listed in table I should provide some insight into comparative costs with relationship to commonly used package cushioning materials. The cost ratios for the materials shown are based on an equivalent volume of polyurethane (ether) material.

TYPE FOAM (2 pcf)	COST RATIO
Polyurethane (ether)	1.0
Polyurethane (ester)	1.3
PU/PS Composite	1.1
Polyethylene	1.4

Table I. Relative Cost Information

Conclusions

When compared to the dynamic cushioning curves of the polyurethane matrix material alone, the addition of expanded polystyrene beads in a polyurethane formulation will decrease the peak acceleration at the high static stress range of the Gm - $\frac{W}{A}$ curves and increase the peak acceleration at the low range. The percentage of polystyrene beads in the formulations will determine the shape of the Gm - $\frac{W}{A}$ curves.

The most significant effect of the polystyrene beads is the "flattening" of the polyurethane Gm - $\frac{W}{A}$ curves such that the level of protection provided remains essentially constant over a wide static stress range. This characteristic simplifies the package design process since one type and thickness of material can be used to package items with widely differing weights and dimensions.

At static stress loads of 0.3 psi and above, composite polyurethane - polystyrene materials provide significantly better protection than polyurethane as drop heights are increased. As an example, the polyurethane will "bottom out" if the static stress is greater than 0.3 psi. If a pack is accidentally dropped at a height which is greater than than the maximum design height, the item will be damaged; whereas, the composite material will continue to provide the same protection to a static stress of 0.6 psi which would be equivalent to drop heights greater than the maximum design drop height.

Recommendations

Generate additional dynamic test data to enable packaging specialists and designers to determine specific applications for this type of composite material. This should include additional drop heights, additional thicknesses and the evaluation of other special polyurethane/polystyrene formulations.

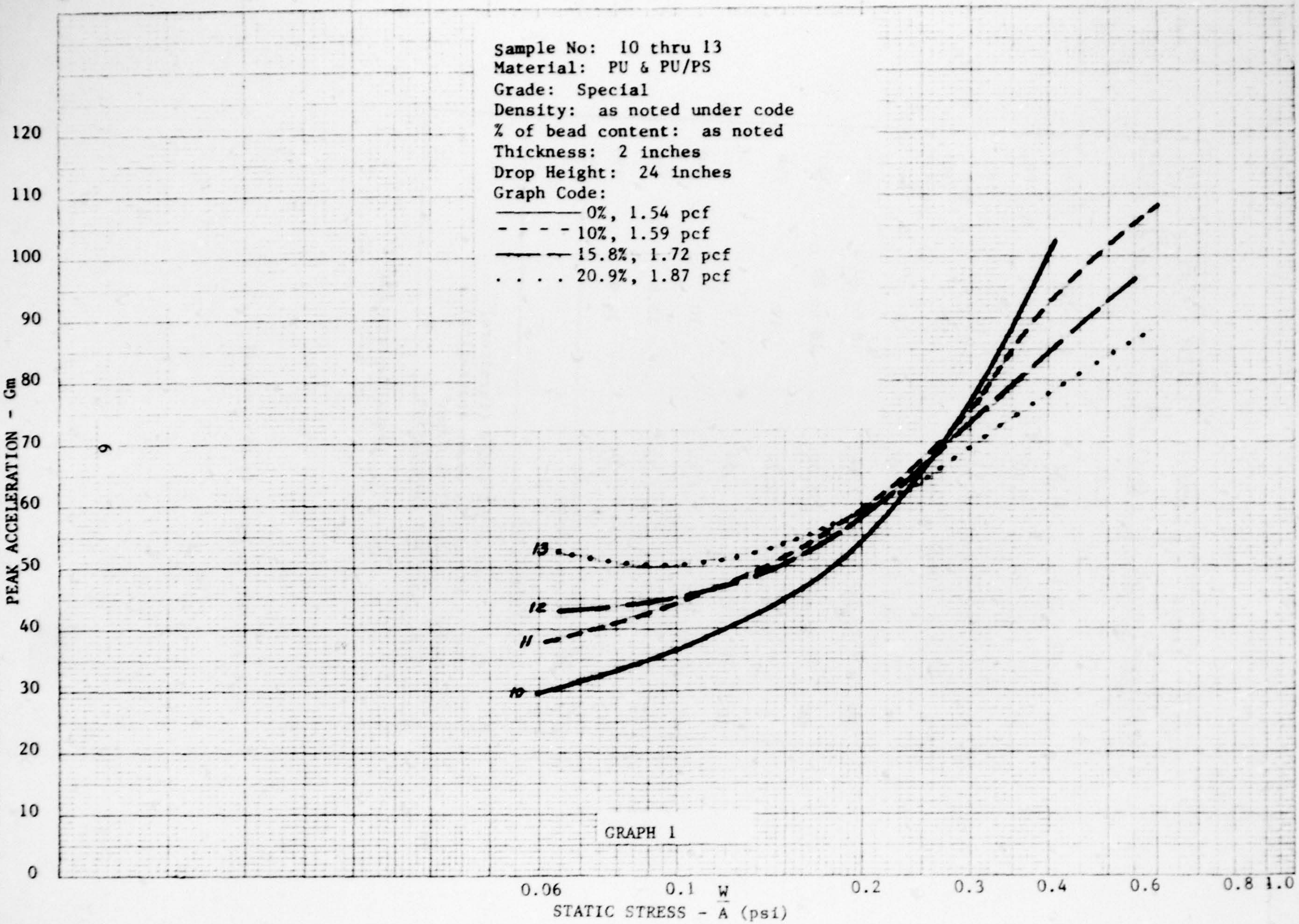
SAMPLE NUMBER	SAMPLE TYPE	SAMPLE GRADE	DENSITY (pcf)	POLYSTYRENE BEAD CONTENT (% by weight)	BEAD SIZE (Micron)
1	PU	-	2.24	0	-
2*	PU/PS	C.G.1	1.82	8 to 10	790
3*	"	C.G.2	2.00	8 to 10	790
4	"	C.G.3	2.11	8 to 10	790
5	"	S.G. (Std)	2.20	15	790
6	"	S.G.1	2.46	18	790
7*	"	Inter. 2	2.16	18 to 20	790
8*	"	Inter. 3	2.00	18 to 20	790
9	"	Inter. X	2.24	13	790
10	PU	S.F. 1	1.54	0	-
11	PU/PS	S.F. 2	1.59	10	950
12	"	S.F. 3	1.72	15.8	950
13	"	S.F. 4	1.87	20.9	950
14	"	S.G	2.52	-	-

TYPE:
PU - Polyurethane
PS - Polystyrene

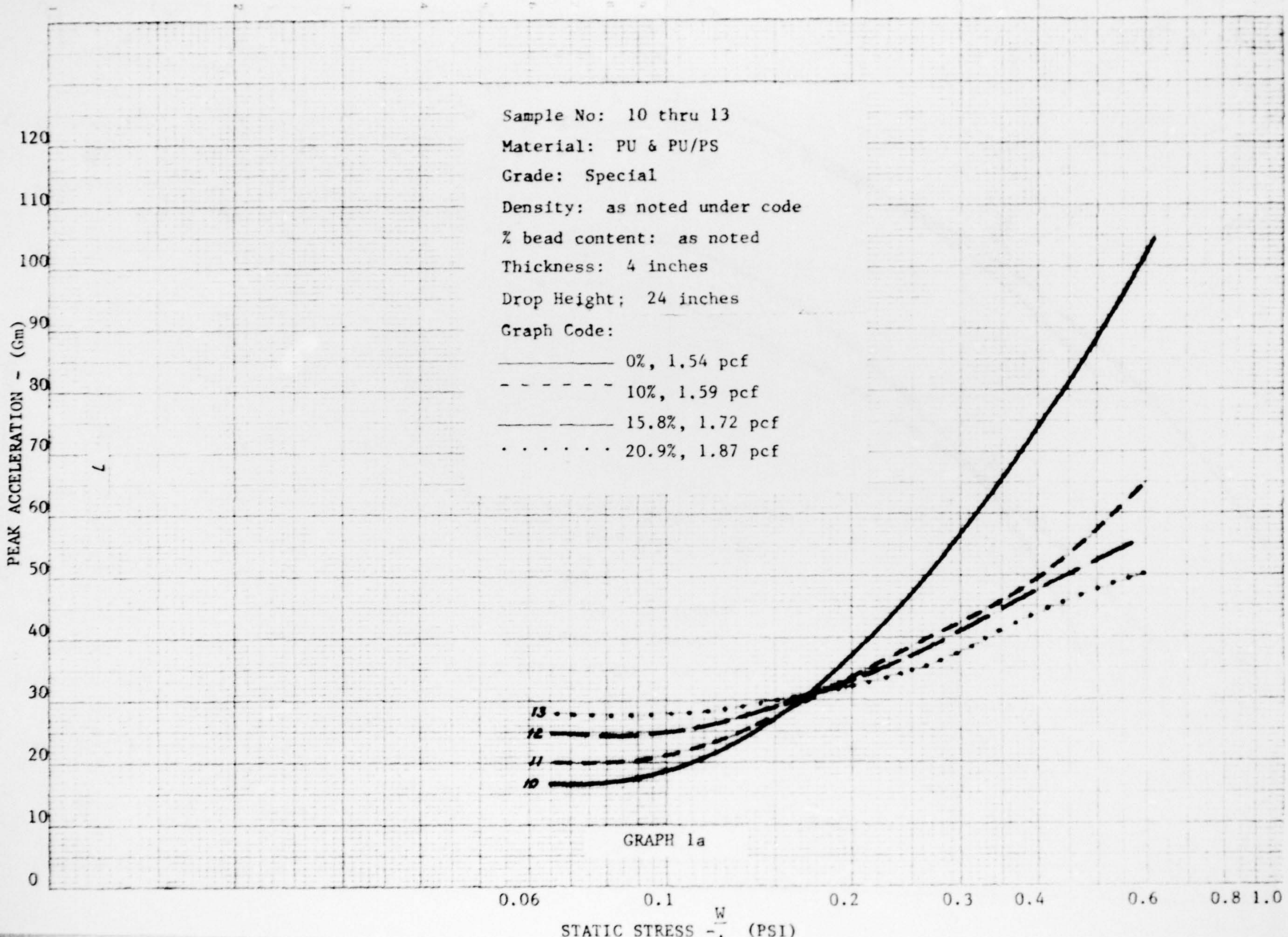
GRADE:
C.G. - Cushioning Grade (furniture)
S.G. - Structural Grade (packaging)
INTER. Intermediate Grade
S.F. - Special Formulation

Table II. Sample Description

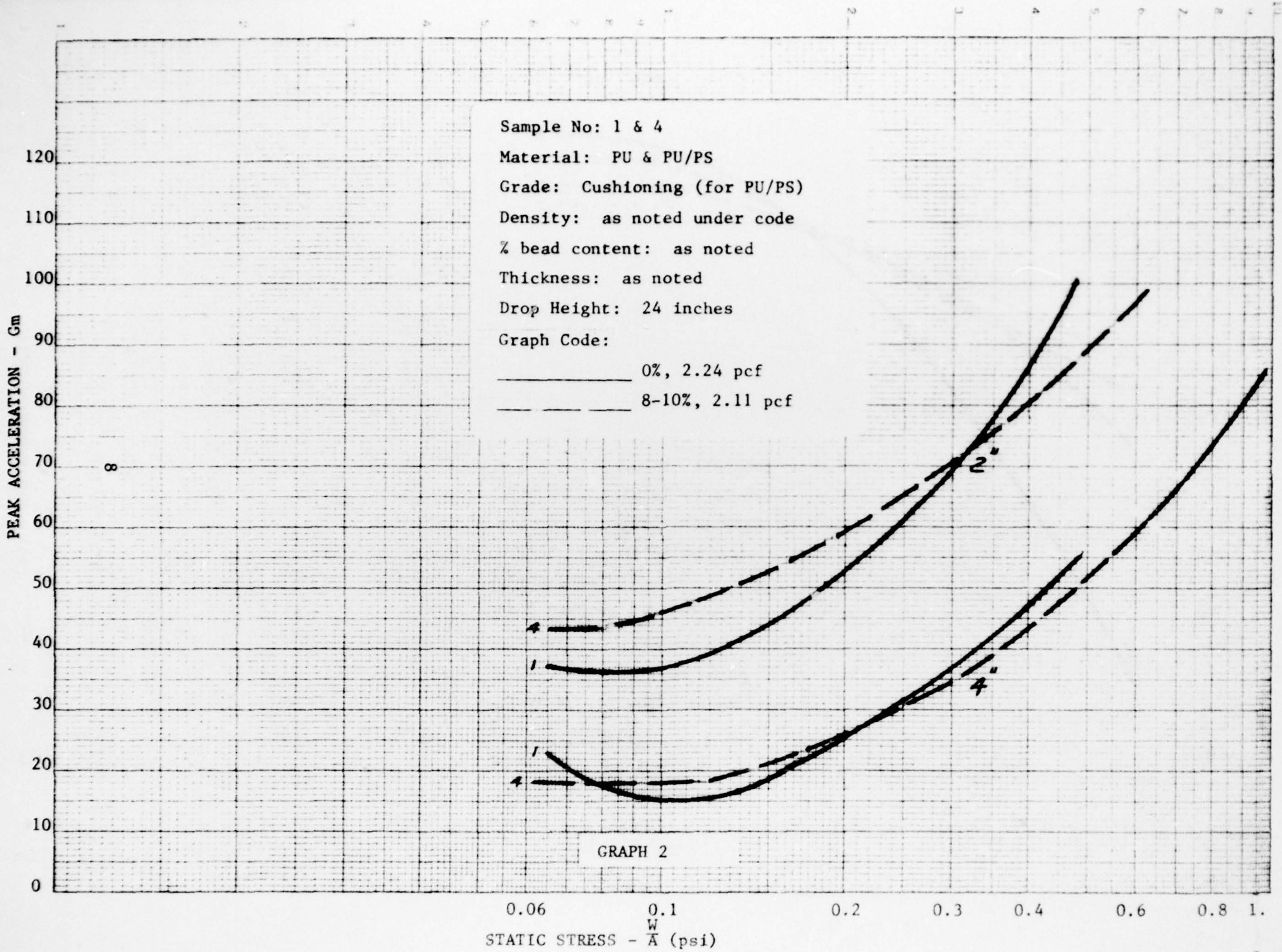
* Graphs not included in this report


Sample No: 10 thru 13
Material: PU & PU/PS
Grade: Special
Density: as noted under code
% of bead content: as noted
Thickness: 2 inches
Drop Height: 24 inches
Graph Code:
———— 0%, 1.54 pcf
- - - - 10%, 1.59 pcf
—— — 15.8%, 1.72 pcf
. . . . 20.9%, 1.87 pcf
PEAK ACCELERATION - Gm
120
110
100
90
80
70
60
50
40
30
20
10
0
0.06
0.1
0.2
0.3
0.4
0.6
0.8
1.0
STATIC STRESS - W/A (psi)
10
11
12
13

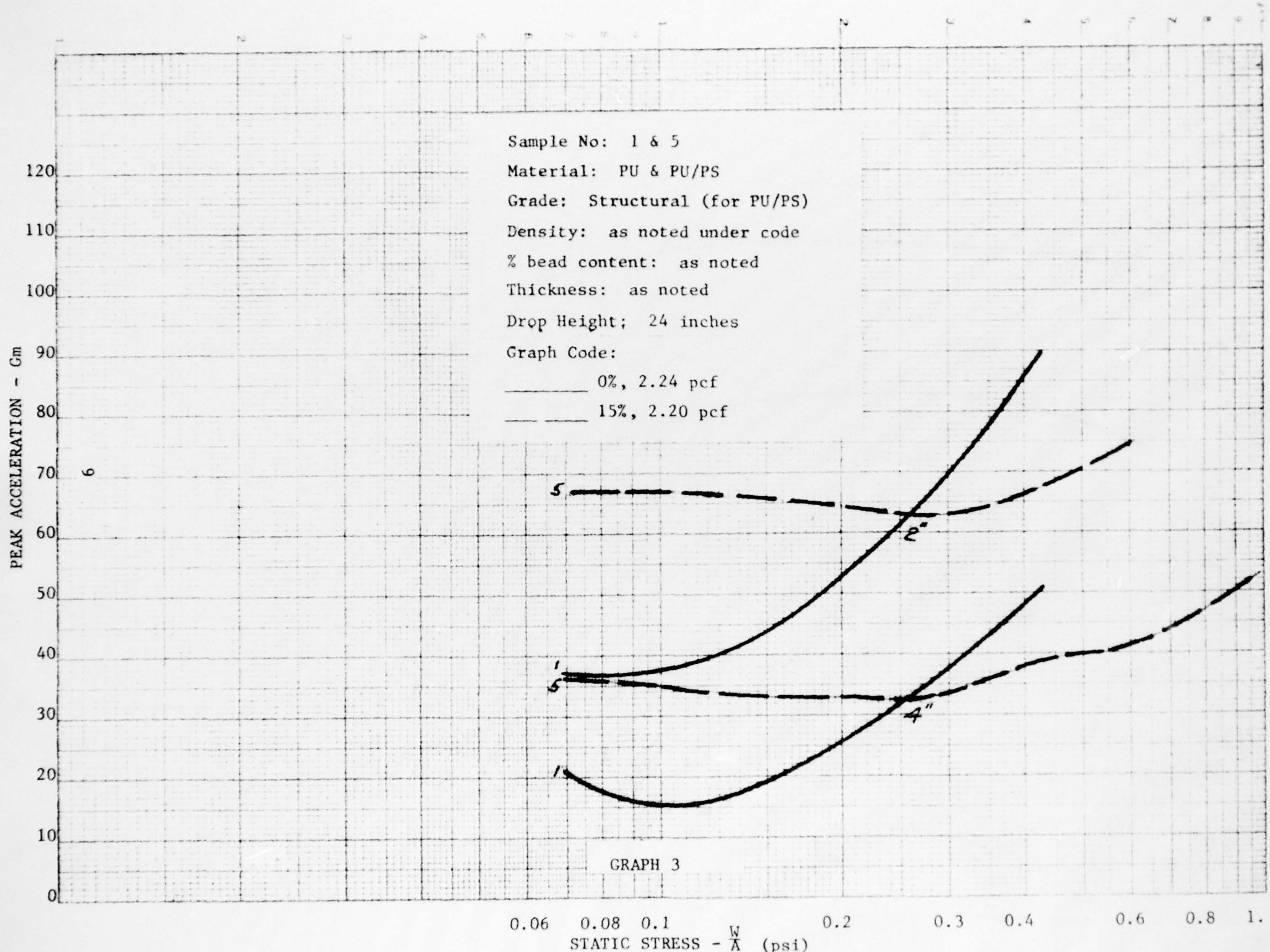
GRAPH 1


Sample No: 10 thru 13
Material: PU & PU/PS
Grade: Special
Density: as noted under code
% bead content: as noted
Thickness: 4 inches
Drop Height; 24 inches
Graph Code:
0%, 1.54 pcf
10%, 1.59 pcf
15.8%, 1.72 pcf
20.9%, 1.87 pcf
13
12
11
10
PEAK ACCELERATION - (Gm)
0
10
20
30
40
50
60
70
80
90
100
110
120
0.06
0.1
0.2
0.3
0.4
0.6
0.8
1.0
STATIC STRESS - W/A (PSI)

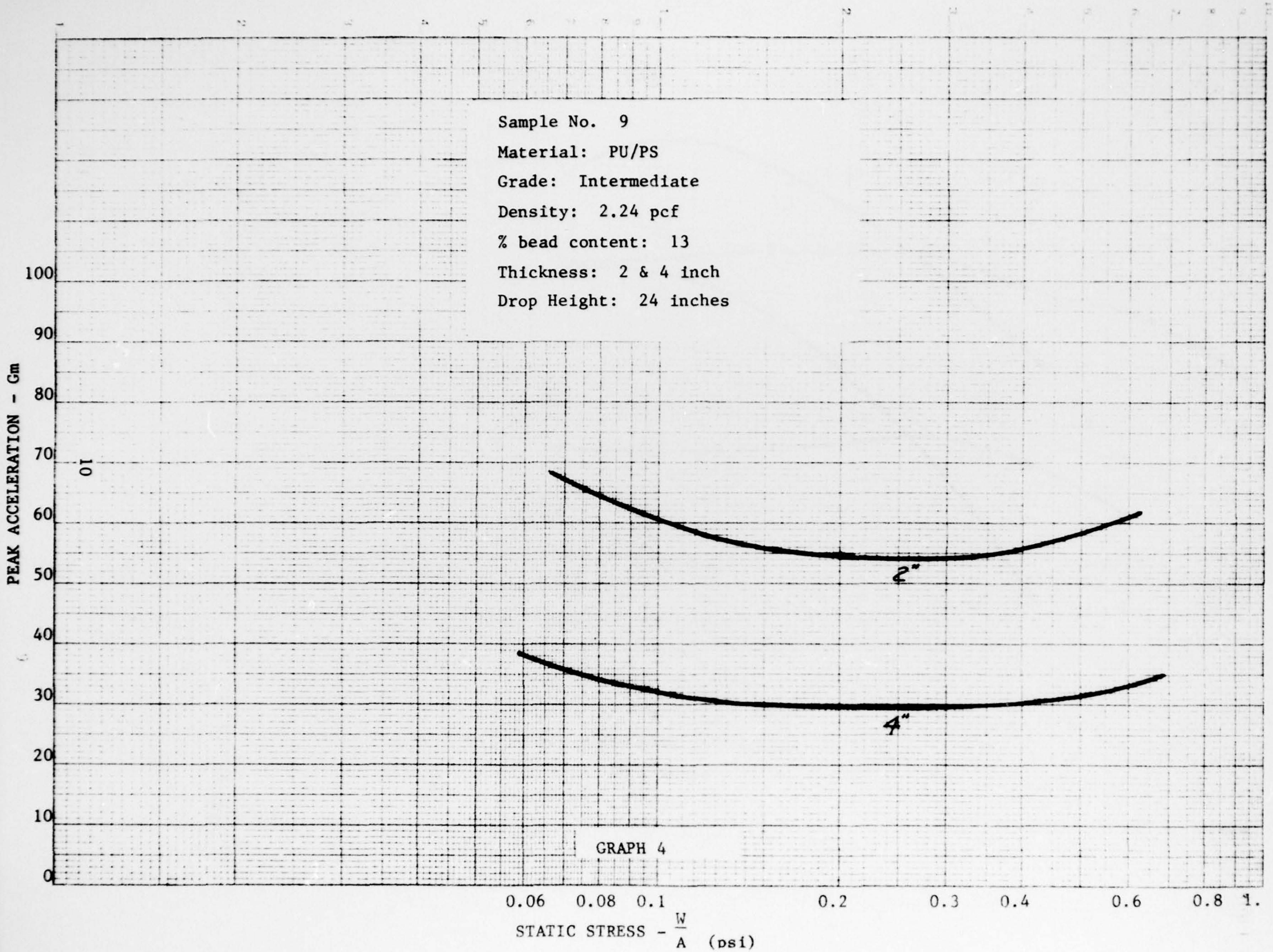
GRAPH 1a


Sample No: 1 & 4
Material: PU & PU/PS
Grade: Cushioning (for PU/PS)
Density: as noted under code
% bead content: as noted
Thickness: as noted
Drop Height: 24 inches
Graph Code:
0%, 2.24 pcf
8-10%, 2.11 pcf
PEAK ACCELERATION - Gm
120
110
100
90
80
70
60
50
40
30
20
10
0
0.06
0.1
0.2
0.3
0.4
0.6
0.8
1.
STATIC STRESS - W/A (psi)
2"
4"

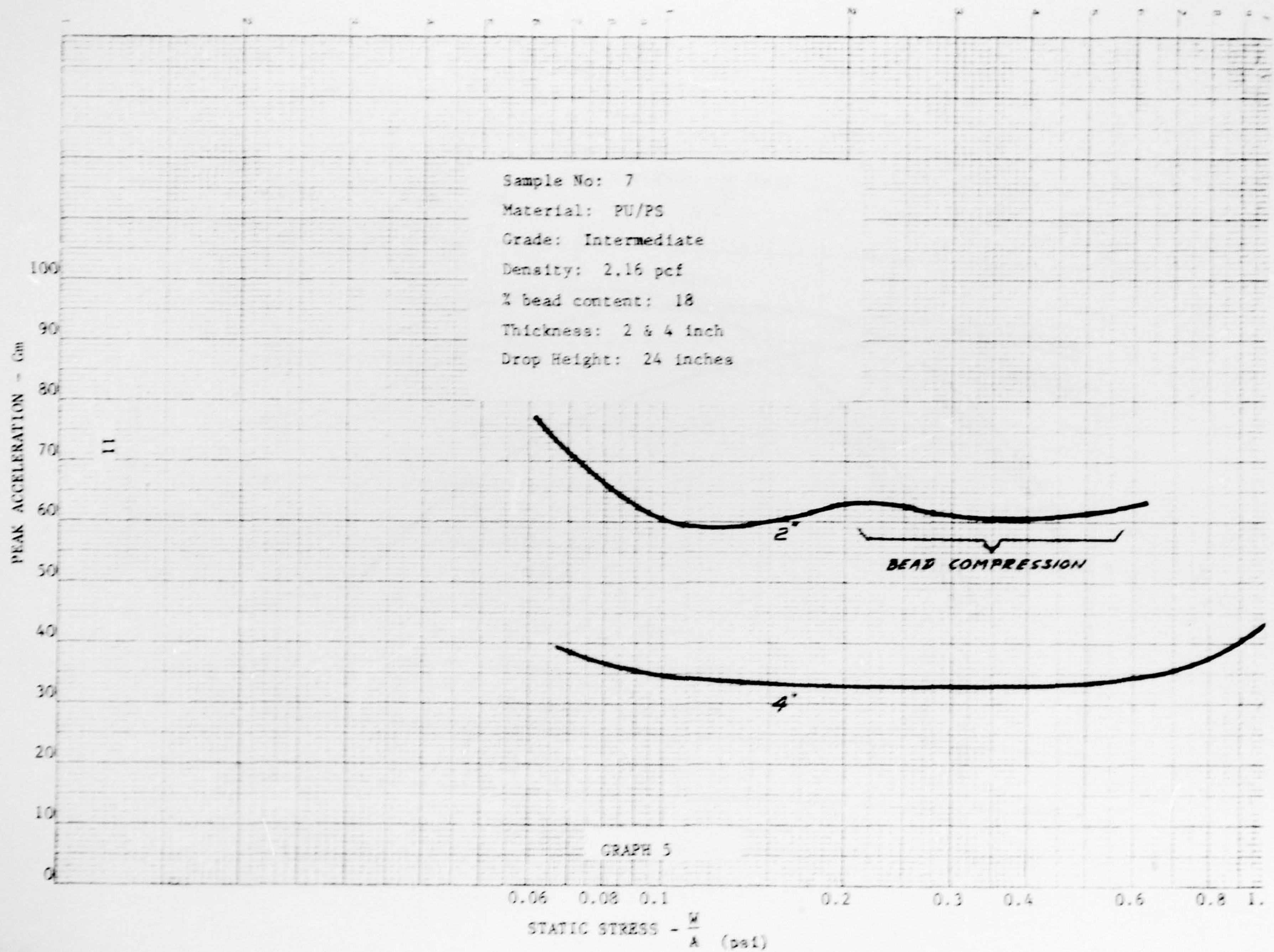
GRAPH 2


Sample No: 1 & 5
Material: PU & PU/PS
Grade: Structural (for PU/PS)
Density: as noted under code
% bead content: as noted
Thickness: as noted
Drop Height; 24 inches
Graph Code:
0%, 2.24 pcf
15%, 2.20 pcf
PEAK ACCELERATION - Gm
120
110
100
90
80
70
60
50
40
30
20
10
0
0.06
0.08
0.1
0.2
0.3
0.4
0.6
0.8
1.
STATIC STRESS - $\frac{W}{A}$ (psi)
5
1
5
1
2"
4"

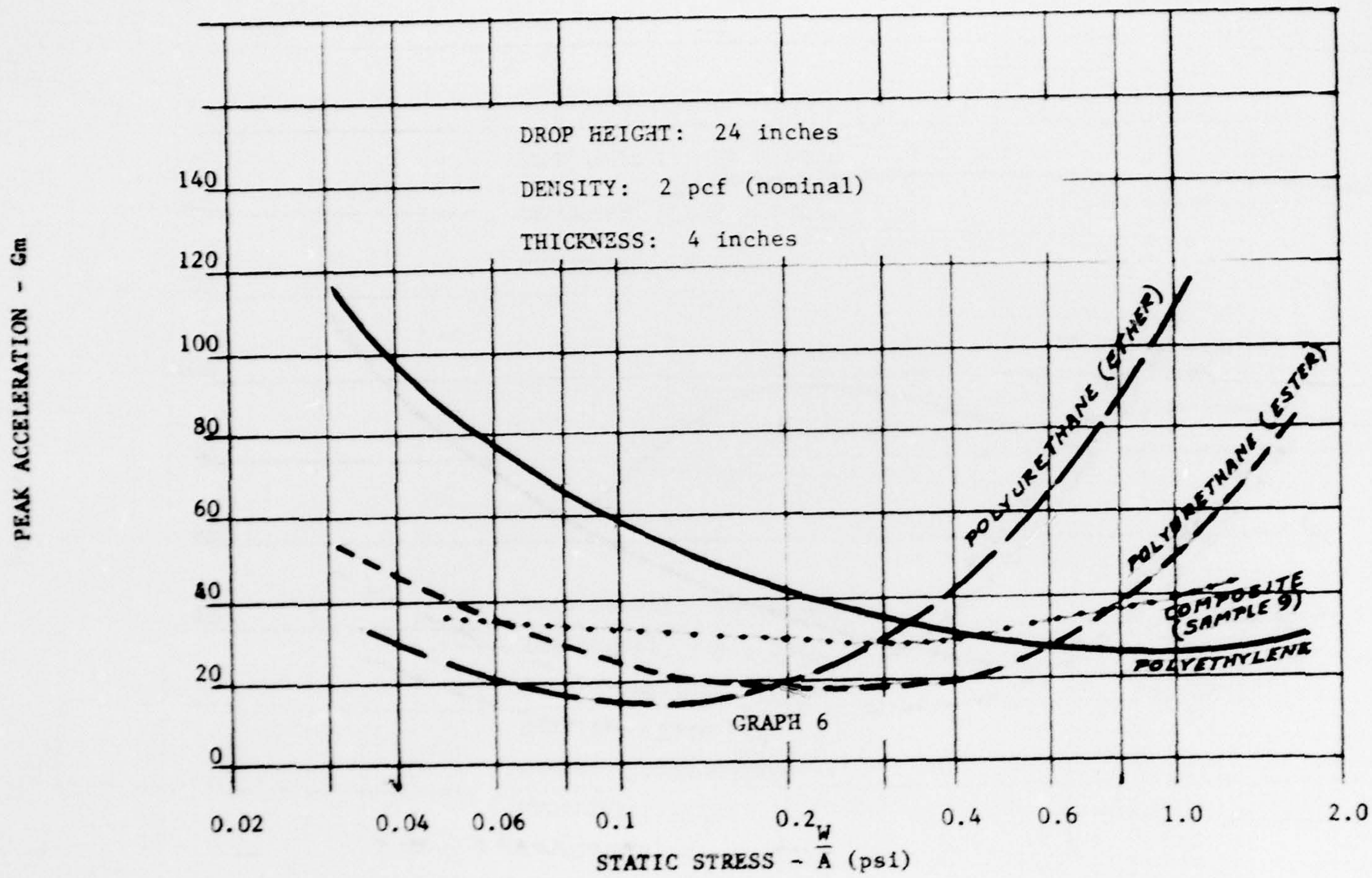
GRAPH 3


Sample No. 9
Material: PU/PS
Grade: Intermediate
Density: 2.24 pcf
% bead content: 13
Thickness: 2 & 4 inch
Drop Height: 24 inches
PEAK ACCELERATION - Gm
100
90
80
70
60
50
40
30
20
10
0
0.06
0.08
0.1
0.2
0.3
0.4
0.6
0.8
1.
STATIC STRESS - W/A (psi)
2"
4"
10

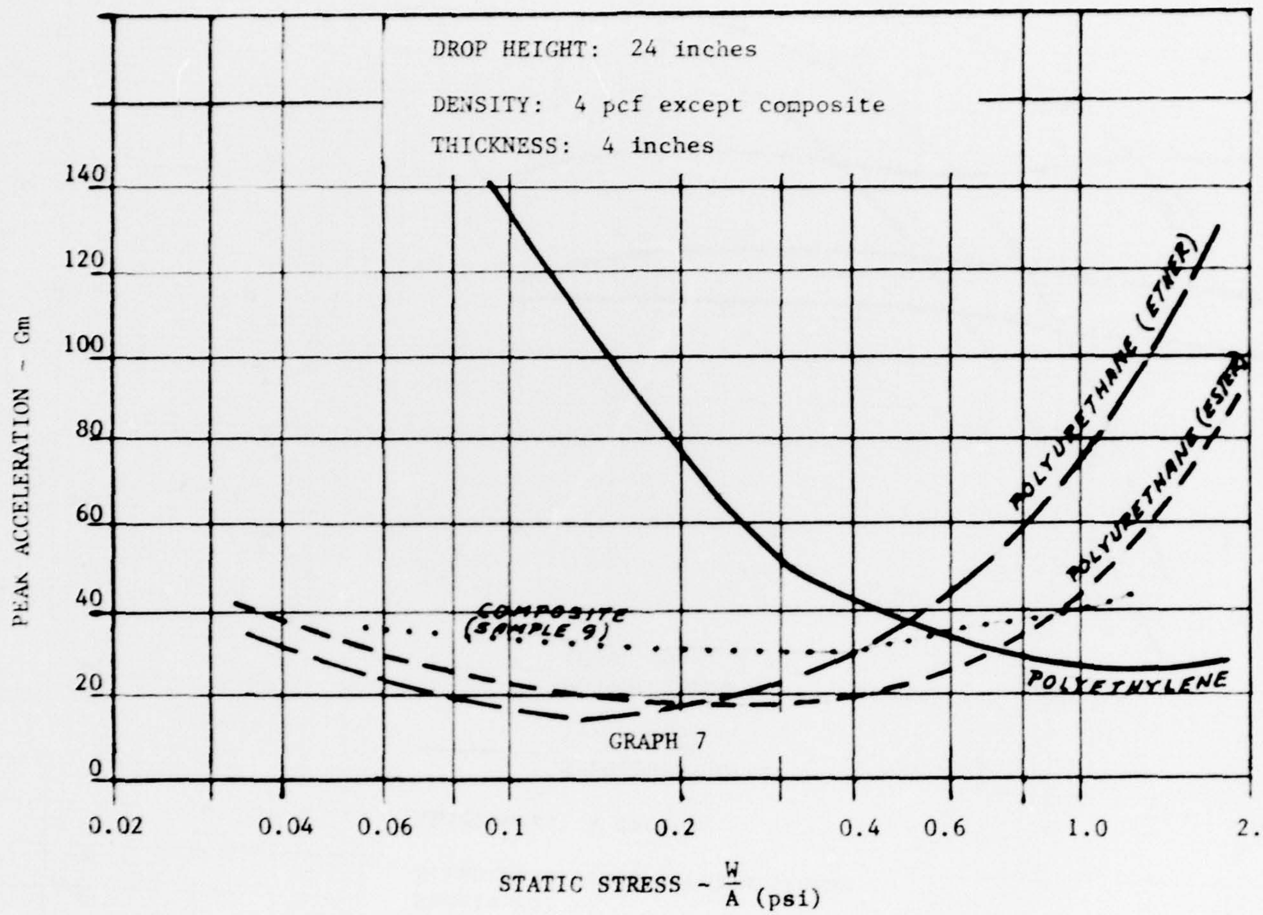
GRAPH 4

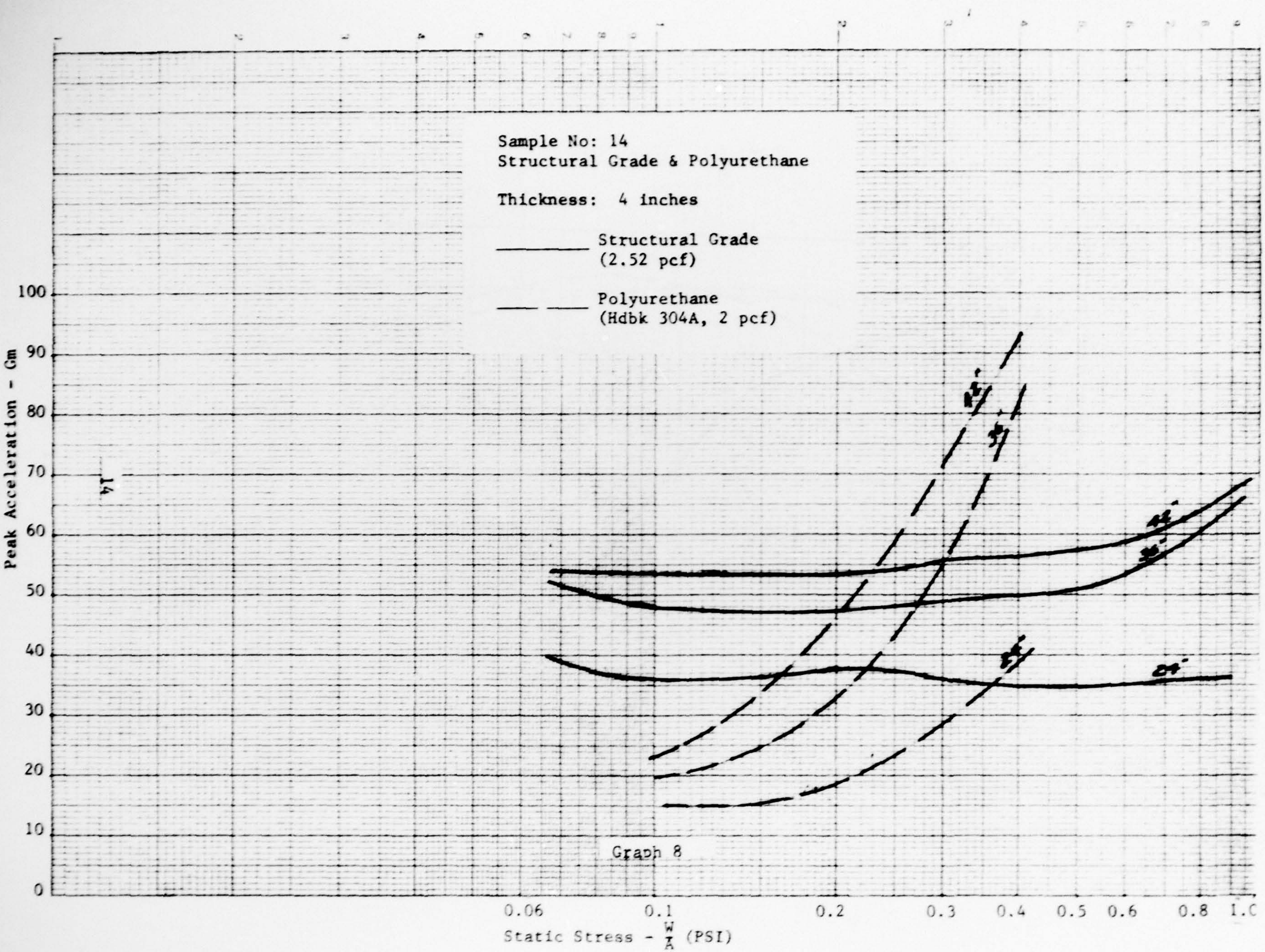

Sample No: 7
Material: PU/PS
Grade: Intermediate
Density: 2.16 pcf
% bead content: 18
Thickness: 2 & 4 inch
Drop Height: 24 inches
PEAK ACCELERATION - Gm
100
90
80
70
60
50
40
30
20
10
0
2"
4"
BEAD COMPRESSION
0.06
0.08
0.1
0.2
0.3
0.4
0.6
0.8
1.
STATIC STRESS - W/A (psi)

GRAPH 5

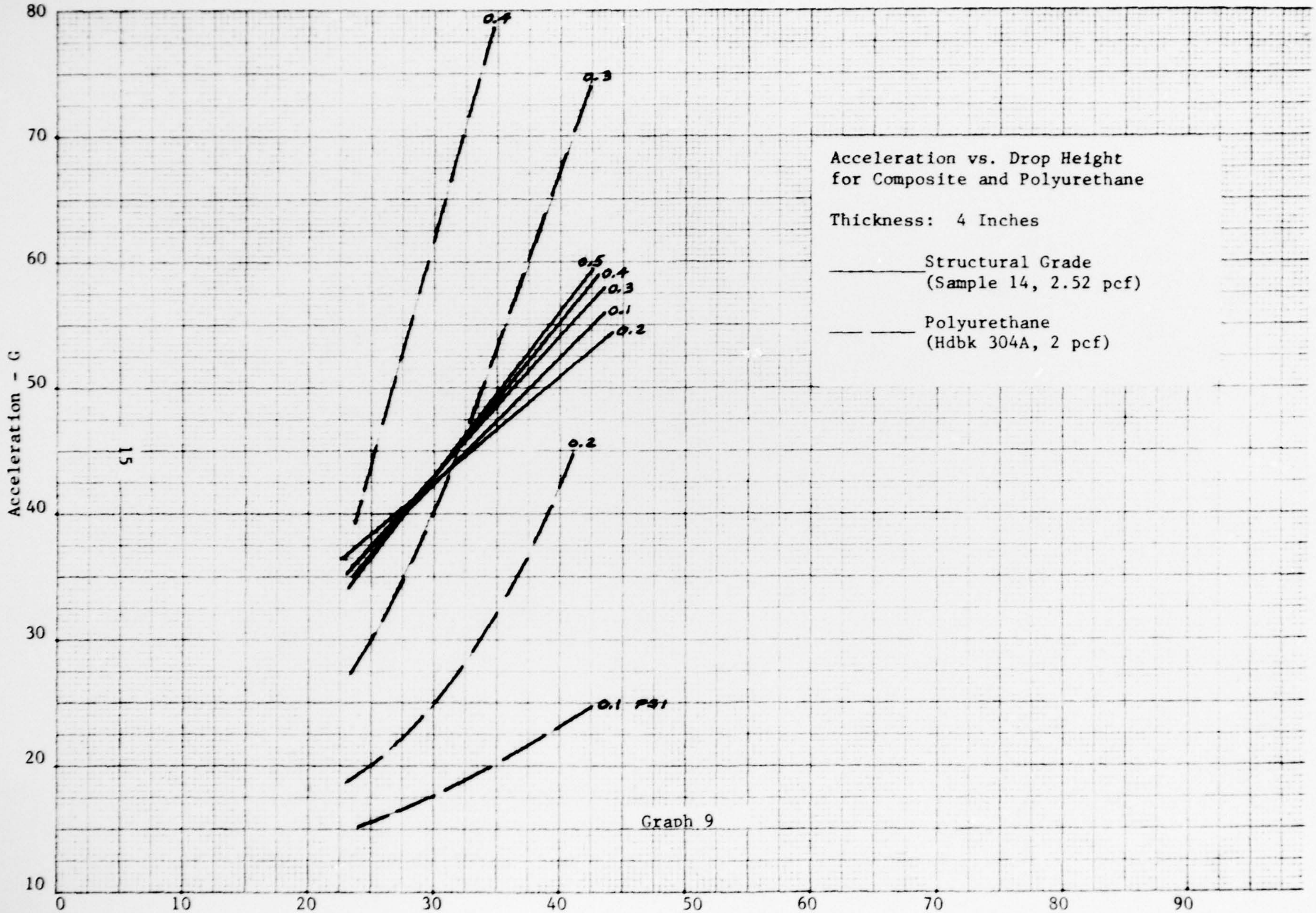

DROP HEIGHT: 24 inches
DENSITY: 2 pcf (nominal)
THICKNESS: 4 inches
PEAK ACCELERATION - Gm
140
120
100
80
60
40
20
0
0.02
0.04
0.06
0.1
0.2
0.4
0.6
1.0
2.0
STATIC STRESS - W/A (psi)
POLYURETHANE (ETHER)
POLYURETHANE (ESTER)
COMPOSITE (SAMPLE 9)
POLYETHYLENE

GRAPH 6


DROP HEIGHT: 24 inches
DENSITY: 4 pcf except composite
THICKNESS: 4 inches
PEAK ACCELERATION - Gm
140
120
100
80
60
40
20
0
0.02
0.04
0.06
0.1
0.2
0.4
0.6
1.0
2.0
STATIC STRESS - W/A (psi)
COMPOSITE (SAMPLE 9)
POLYURETHANE (ETHER)
POLYURETHANE (ESTER)
POLYETHYLENE
GRAPH 7


Sample No: 14
Structural Grade & Polyurethane
Thickness: 4 inches
Structural Grade (2.52 pcf)
Polyurethane (Hdbk 304A, 2 pcf)
Peak Acceleration - Gm
0
10
20
30
40
50
60
70
80
90
100
0.06
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
Static Stress - $\frac{W}{A}$ (PSI)

Graph 8


Acceleration vs. Drop Height
for Composite and Polyurethane
Thickness: 4 Inches
Structural Grade
(Sample 14, 2.52 pcf)
Polyurethane
(Hdbk 304A, 2 pcf)
Acceleration - G
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
0.4
0.3
0.5
0.4
0.3
0.1
0.2
0.2
0.1 PSI

Graph 9

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Packaging, cushioning material, composite, Gm - W/A curves

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An evaluation of a polyurethane/polystyrene composite cushioning material revealed that the dynamic cushioning characteristics of this material has a broader static stress range, for a specific peak acceleration, than some of the existing 2 pcf materials listed in Military Handbook 304A, "Package Cushioning Design." Samples of materials identified as structural grade and cushioning grade together with intermediate grades of material formulations, were analyzed to determine the effect of the expanded polystyrene beads in the material formulation.

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